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QUALITY OF GRAPEFRUIT IMPORTED INTO WESTERN EUROPE

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On January 24, 1978, four USDA agencies--Agricultural Research Service (ARS), Cooperative State Research Service (CSRS), Extension Service (ES), and the National Agricultural Library (NAL)--merged to become a new organization, the Science and Education Administration (SEA), U.S. Department of Agriculture.

This publication was prepared by the Science and Education Administration's Federal Research staff, which was formerly the Agricultural Research Service.

PREFACE

This study is part of a broad program of research by the Science and Education Administration on the problems of shipping and marketing agricultural products overseas. Specifically the object of this report is to compare several quality factors of grapefruit exported to Europe from various countries.

The following companies in Rotterdam, the Netherlands, are acknowledged for donating grapefruit for the study: Velleman en Tas B. V., J. van den Brink B. V., Jac. van den Berg B. V., Algemene Vruchten Import Maatschappij B. V., Citronas B. V., and Internationale Fruit Maatschappij B. V. The cooperation of the Citrus Marketing Board of Israel and the South African Co-operative Citrus Exchange Ltd. is appreciated.

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The research was done under the general supervision of Philip L. Breakiron, Chief, Transportation and Packaging Research Laboratory, Science and Education Administration, Beltsville.

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QUALITY OF GRAPEFRUIT IMPORTED INTO WESTERN EUROPE

By Ben M. Hillebrand, Lawrence A. Risse, and Anton J. Bongers[1/]

ABSTRACT

The variation of three physical and three chemical characteristics of fresh 'Marsh Seedless' and 'Ruby Red' grapefruit imported into Western Europe from various origins was studied in 1974. These characteristics included fruit size, fruit weight, rind thickness, juice volume, total soluble solids, and total acid. The juice-to-fruit-weight ratio and solids-to-acid ratio were calculated from the individual factors. Considerable differences between these characteristics by country of origin were found.

Significant statistical findings were as follows:

- In comparing fruit size per given count, Marsh Seedless grapefruit from Cyprus and Israel was larger than fruit from other origins.

- Marsh Seedless grapefruit from the Northern Hemisphere was most often heavier than grapefruit from the Southern Hemisphere. Little difference in weight was found in the Ruby Red cultivar.

- Marsh Seedless fruit from Florida had the thinnest rind and from Brazil the thickest.

- Florida Marsh Seedless and Ruby Red fruit generally had the highest juice-to-fruit-weight ratio, with Honduras ranking second.

- The highest percentage of total soluble solids was found in Marsh Seedless fruit from Cyprus.

- Marsh Seedless and Ruby Red grapefruit from Florida had the lowest percentage of total acid compared with fruit from other origins.

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- Marsh Seedless grapefruit from Florida and Surinam had the highest solids-to-acid ratios compared with fruit from other origins. Florida Ruby Red fruit had the highest solids-to-acid ratio.

- Correlation analyses were used to evaluate the data.

INTRODUCTION

In 1973, the population of Western Europe was 373 million people, of which 256 million were living in the European Economic Community (EEC) countries (2). 2/ The consumption and therefore the demand for grapefruit have been increasing yearly within the EEC.

In 1974, the imports of fresh grapefruit into the EEC totaled 337,353 metric tons from at least 26 countries of origin (table 1). The five countries that exported the largest quantities of fresh grapefruit into the EEC countries were Israel, South Africa, Cyprus, the United States, and Argentina. In 1974, the United States exported 26,043 metric tons, which represented 7.7 percent of the total imports into the EEC. In 1975, it exported 52,985 metric tons, which represented 13.3 percent of the total imports into the EEC. Imports from all countries of origin increased 17.8 percent in 1975 as compared with 1974. The Netherlands imported 34,870 metric tons of grapefruit in 1974 (table 1), of which 23,000 metric tons were sold through the Rotterdam Citrus Auction, the Netherlands (2).

The EEC Commission does not have quality standards for fresh grapefruit in its regulations (1) on common quality standards for citrus fruits. The EEC members have voluntarily accepted as an advice standard, Standard No. 7 of the Organization for Economic Cooperation and Development, in which quality standards for fresh grapefruit are included (8). However, this standard is not used by the inspection services in the member countries and is therefore not binding.

Most exporting countries promote their fresh grapefruit by claiming that it has the highest quality or is the sweetest or the juiciest. Some grapefruit is grown under climatic conditions that promote wind scarring and other surface blemishes, but these do not affect the internal quality. Also insect and snail damage to the peel does not affect internal characteristics.

Harding and Fisher (4) studied the seasonal changes in Florida grapefruit and the effects of lead arsenate spray on the composition and quality of 'Marsh' and 'Duncan' grapefruit. Long et al. (6, 7) reported on variations in quality of Florida-grown Duncan grapefruit and of Marsh grapefruit. Rygg and Getty (9) reported on the seasonal changes in Arizona and California grapefruit.

The objective of this study was to determine the extent of variation in three physical and three chemical characteristics in the quality of fresh grapefruit imported into the EEC countries from various origins.

2/ Underlined numbers in parentheses refer to Literature Cited at the end of this report.

TABLE 1.--Grapefruit imports into EEC countries by country of origin, 1974[1/]

Country of origin	France	United Kingdom	Italy	Netherlands	Belgium and Luxembourg	Western Germany	Denmark	Total	Proportion of total imports
	Metric tons	Metric tons	Metric tons	Metric tons	Metric tons	Metric tons	Metric tons	Metric tons	Percent
Argentina	3,711	3,558	---	5,426	103	2,735	15	15,548	4.60
Australia	---	---	---	---	---	---	20	20	.01
Belize	---	1,868	---	49	---	---	---	1,917	.57
Brazil	---	331	---	193	---	228	---	752	.22
Cuba	---	---	---	306	---	271	44	621	.18
Cyprus	---	23,078	1,983	5,166	1,027	6,140	60	37,454	11.10
Egypt	---	---	---	---	---	468	3	471	.14
Equador	---	---	---	---	37	---	---	37	.01
Honduras	---	---	---	2,137	527	4,405	413	7,482	2.22
Israel	35,248	43,713	24,473	10,421	9,700	58,816	2,109	184,480	54.68
Jamaica	---	274	---	---	---	---	---	274	.08
Mexico	403	---	---	86	18	375	---	882	.26
Morocco	---	---	---	---	---	189	---	189	.06
Mozambique	294	2,801	---	1,091	---	3,019	18	7,223	2.14
Nigeria	---	---	---	4	---	---	---	4	.00
Paraguay	---	---	---	505	---	62	---	567	.17
South Africa[2/]	4,268	16,059	4,760	1,153	1,925	11,307	394	39,866	11.82
Spain	---	---	---	12	10	212	---	234	.07
Surinam	---	---	---	1,521	---	---	---	1,521	.45
Trinidad and Tobago	---	66	---	16	---	---	---	82	.02
Turkey	---	---	---	---	---	260	---	260	.08
United States	12,832	1,503	---	4,237	1,379	5,929	163	26,043	7.72
Uruguay	---	---	---	69	---	---	---	69	.02
Venezuela	---	---	---	9	---	---	---	9	.00
Zaire	---	---	---	---	2	---	---	2	.00
Unspecified origin	469	4,174	1,320	---	---	105	13	6,081	1.80
Through other EEC countries	---	1,176	---	2,469	1,549	71	---	5,265	1.56
Total	57,225	98,601	32,536	34,870	16,277	94,592	3,252	337,353	99.98

1/ Source: Productschap voor Groenten en Fruit, The Hague, the Netherlands.
2/ Including Swaziland.

MATERIALS AND METHODS

Grapefruit samples were collected randomly by U.S. Department of Agriculture personnel from lots displayed at the Rotterdam Citrus Auction. Collections were made only on auction days, which were generally twice weekly, from the first of January to the last of December during 1974.[3/] The samples of fruit displayed at the auction were selected by a nonpartisan body from the lots to be sold. (As of 1975, the samples displayed were selected by the importers.) Each lot or shipment was sampled only once for this study. If a particular lot had been sampled the previous week, samples were not taken again.

A five-fruit sample of every size, larger than indicated count 30, was obtained from every country. This is a standard sample as described by Soule et al. (10). A total of 814 samples were collected from 13 countries of origin. The samples from the United States were further broken down into those from California, Florida, and Texas, totaling 15 points of origin. The 814 samples were classified into the cultivars Marsh Seedless and Ruby Red in addition to pink cultivars. Since the number of samples of pink grapefruit was very small, their data were deleted from statistical analyses, as well as data of fruit samples from Cuba, Mexico, Texas, and Trinidad, leaving 11 points of origin. For the same reason, data from certain indicated counts also were deleted from the statistical analyses, leaving 713 samples of the cultivar Marsh Seedless and 53 samples of the cultivar Ruby Red.

The following data were determined for each sample:

Fruit size: The diameter of each fruit was measured to the nearest millimeter at the equator.

Fruit weight: The total weight of the five-fruit sample was determined to the nearest gram.

Rind thickness: The thickness of the rind was measured to the nearest millimeter between section membranes after cutting transversely at the equator.

Juice volume: The five-fruit samples were juiced with a Sunkist Juice Extractor, type 7. The juice was strained through a 1.2-mm strainer to separate the seeds and pulp from the juice. The strained juice was measured in a graduated cylinder to obtain the juice volume of five fruits to the nearest milliliter.

Total soluble solids: The total soluble solids were determined with a Bausch and Lomb refractometer, model 362 CD, which measured from 0 to 25 percent.

Total acid: Total acid was measured by titrating a 25-ml juice sample with a sodium hydroxide solution to the phenolphthalein end point and is expressed as percent anhydrous citric acid.

[3/] Although the research was conducted in 1974, the findings are still valid except minor variations due to seasonal changes in the physical and chemical characteristics of the grapefruit.

In addition to these measurements, the juice-to-fruit-weight ratio and solids-to-acid ratio were calculated from the means of the individual factors. The juice-to-fruit-weight ratio is the amount of juice of the five-fruit sample divided by the weight of this sample; it is expressed as the amount of juice in milliliters per 100 grams of fruit. The proportion of total soluble solids to total acid, or solids-to-acid ratio, was calculated by dividing the percentage of total soluble solids by the percentage of total acid.

Analyses of variance and Duncan's multiple range test (3), modified by the method of Kramer (5), and correlation analyses were used when appropriate to evaluate the data.

RESULTS

The physical and chemical characteristics of Marsh Seedless and Ruby Red grapefruit differed considerably by country of origin, based on sampling at the Rotterdam Citrus Auction (table 2).

Florida and Cyprus exported significantly larger Marsh Seedless grapefruit than the other countries except Honduras. Marsh Seedless grapefruit from California, South Africa, and Paraguay was significantly smaller than fruit from other countries except Brazil and Mozambique. Florida exported significantly larger Ruby Red grapefruit than Argentina.

Marsh Seedless and Ruby Red grapefruit from Florida and Honduras were significantly heavier than fruit from all other origins.

Marsh Seedless grapefruit from Florida had significantly thinner rind than fruit from all other places except Paraguay. Ruby Red fruit from Florida had significantly thinner rind than fruit from Honduras.

The absolute juice volume of Florida Marsh Seedless grapefruit was significantly higher than that from all other origins. Ruby Red grapefruit from Florida and Honduras had significantly higher absolute juice volume than fruit from Argentina.

A more realistic measure is the juice-to-fruit-weight ratio or the amount of juice per 100 grams of fruit. The juice-to-fruit-weight ratio for Florida, Honduras, and Paraguay Marsh Seedless grapefruit was significantly higher than that for fruit from all other places, except the ratio for fruit from Paraguay was not significantly higher than that from South Africa. There was no significant difference in the juice-to-fruit weight ratio for Ruby Red grapefruit.

The percentage of total soluble solids and total acid for Marsh Seedless grapefruit from Cyprus was significantly higher than that for fruit from all other origins. There was no difference in the percentage of soluble solids for the origins of Ruby Red grapefruit.

The percentage of total acid for both Marsh Seedless and Ruby Red grapefruit from Florida was significantly lower than that for fruit from all other origins.

TABLE 2.--Physical and chemical characteristics of Marsh Seedless and Ruby Red grapefruit by country of origin, Rotterdam, 1974 1/

Origin	Samples	Fruit size	Fruit weight	Rind thickness	Juice volume	Juice-to-fruit-weight	Total soluble solids	Total acid	Solids-to-acid
	Number	Mm	Grams	Mm	Ml	Ratio	Percent	Percent	Ratio
				Marsh Seedless grapefruit					
Argentina-----	68	88.1 b	1,328.5 de	7.3 b	525.6 e	39.5 e	9.0 d	1.9 b	4.8 d
Brazil--------	11	86.1 bc	1,236.1 de	8.8a	490.5 e	39.8 de	8.9 de	1.9 b	4.7 d
California----	84	82.9 c	1,296.8 de	6.1 d	522.0 e	40.1 de	10.7 b	1.8 b	6.1 b
Cyprus--------	48	92.6a	1,535.6 bc	7.0 bc	660.6 c	43.1 c	11.7a	2.2a	5.5 cd
Florida-------	24	93.0a	1,830.9a	5.2 e	872.9a	47.7a	8.8 de	1.3 d	7.3a
Honduras------	141	91.2ab	1,716.7a	6.1 d	792.0 b	46.4a	9.8 c	1.6 c	6.2 b
Israel--------	127	87.9 b	1,425.8 cd	6.1 d	619.8 cd	43.5 c	10.8 b	1.8 b	6.0 b
Mozambique----	22	86.5 bc	1,348.2 de	6.5 cd	568.4 de	42.4 cd	7.9 e	1.5 c	5.3 cd
Paraguay------	23	82.4 c	1,214.4 e	5.5 de	556.5 de	45.9ab	8.7 de	1.5 c	5.8 bc
South Africa--	64	82.6 c	1,199.2 e	6.2 d	529.8 e	44.0 bc	9.4 d	1.6 c	6.1 b
Surinam-------	101	88.7 b	1,554.1 b	6.2 d	658.5 c	42.4 cd	10.4 b	1.5 c	7.1a
				Ruby Red grapefruit					
Argentina-----	15	86.7 b	1,401.3 b	4.8ab	703.7 b	49.8a	8.5a	1.5a	5.7 b
Florida-------	21	93.0a	1,823.1a	4.6 b	892.4a	49.4a	9.6a	1.0 b	9.6a
Honduras------	17	91.8ab	1,784.5a	5.4a	844.1a	47.1a	9.4a	1.6a	6.1 b

1/Means within a column followed by different letters are significantly different at 5-percent level.

The solids-to-acid-ratio for Florida and Surinam Marsh Seedless grapefruit was significantly higher than that for fruit from all other origins. Florida Ruby Red grapefruit also had a significantly higher solids-to-acid ratio than fruit from Argentina or Honduras.

Fruit Size

The fruit size in millimeters per indicated count varied from country to country (table 3). The count on the shipping container is a measure of the fruit size. The sizes of the shipping containers varied from origin to origin. The citrus industries of the various countries had their own regulations concerning fruit size.

For any given count, Marsh Seedless grapefruit from Cyprus and Israel was significantly larger than fruit from other origins except for indicated count 88, where fruit from Surinam was larger than fruit from Israel. Generally the Marsh Seedless grapefruit from Brazil, California, Paraguay, and South Africa was the smallest, with most indicated counts significantly smaller.

Florida's Ruby Red grapefruit for indicated count 40 only was significantly larger than fruit from Honduras.

Fruit Weight

The fruit weight in grams for Marsh Seedless and Ruby Red grapefruit by country of origin and indicated count varied significantly (table 4).

In general, Marsh Seedless grapefruit from the Northern Hemisphere was heavier than that from the Southern Hemisphere. Marsh Seedless grapefruit from Cyprus and Israel was heavier per indicated count than that from all other origins, and fruit from Brazil and Mozambique weighed the least.

Ruby Red grapefruit from Argentina for count 64 weighed significantly less than that from Florida or Honduras.

Rind Thickness

The rind thickness in millimeters for Marsh Seedless and Ruby Red grapefruit by country of origin and indicated count is shown in table 5.

Within counts 32, 40, 48, and 56, the fruit from Florida had a thinner rind, and within counts 36, 40, 48, 56, 64, and 72, fruit from Brazil had a thicker rind than that from all other origins, although many comparisons do not show statistical significance.

Ruby Red grapefruit from Florida generally had a thinner rind than that from Argentina or Honduras, and sometimes the difference was statistically significant.

TABLE 3.--Fruit size for Marsh Seedless and Ruby Red grapefruit by country of origin and indicated count, Rotterdam, 1974[1/]

Origin	Size for indicated count									
	32	36	40	48	56	64	72	75	80	88
	Mm	Mm	Mm	Mm	Mm	Mm	Mm	Mm	Mm	Mm
Marsh Seedless grapefruit										
Argentina	---	104.4a	98.1 b	93.6 b	89.4 b	86.5 b	82.2 b	---	78.5 b	78.2 bc
Brazil	---	94.4 b	93.9 bc	89.8 bc	84.2 def	82.1 cde	78.9 bcd	---	---	---
California	---	97.6 b	94.4 bc	89.5 c	85.3 de	81.2 de	73.7 e	---	76.4 bc	72.5 d
Cyprus	---	---	104.7a	98.9a	93.9a	89.1a	86.6a	---	82.9a	---
Florida	103.2 b	---	96.8 bc	92.7 b	85.7 de	---	---	---	---	---
Honduras	107.3a	101.4a	95.6 bc	91.3 b	87.3 cd	84.1 c	---	---	70.0 d	74.3 cd
Israel	---	---	103.3a	97.1a	93.9a	88.6a	---	83.4	---	79.4 b
Mozambique	104.0ab	98.1 b	92.1 c	86.9 c	82.3 f	78.6 e	75.5 de	---	---	---
Paraguay	---	---	96.6 bc	89.8 bc	89.1 bc	83.4 cd	80.3 bc	---	76.6 bc	72.2 d
South Africa	---	94.8 b	92.7 c	87.7 c	83.6 ef	79.6 e	76.8 de	---	75.4 bcd	---
Surinam	104.9ab	101.9a	95.2 bc	89.4 c	86.6 cd	82.1 cd	78.8 cd	84.8	74.8 cd	88.8a
Ruby Red grapefruit										
Argentina	---	103.0	98.2ab	92.5	87.3	83.7	81.4	---	80.7	76.8
Florida	108.6	---	99.6a	92.2	86.9	84.4	---	---	---	---
Honduras	106.4	99.1	95.9 b	92.3	87.6	84.2	---	---	---	---

[1/] Means within a column followed by different letters are significantly different at 5-percent level.

TABLE 4.--Fruit weight for Marsh Seedless and Ruby Red grapefruit by country of origin and indicated count, Rotterdam, 1974[1/]

Origin	Weight for indicated count									
	32	36	40	48	56	64	72	75	80	88
	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams
Marsh Seedless grapefruit										
Argentina	---	2,057.0abc	1,675.0 ef	1,531.2 bc	1,376.7 d	1,231.4 c	1,170.7 b	---	959.7 c	996.0 bc
Brazil	---	1,471.0 d	1,517.0 f	1,329.0 c	1,175.7 e	1,112.5 cd	1,005.5 bc	---	---	---
California	---	1,983.5 bc	1,826.7 cde	1,584.9 b	1,393.0 cd	1,205.6 c	915.5 c	---	1,026.5 b	894.0 c
Cyprus	---	---	2,024.7 b	1,752.9a	1,509.2ab	1,421.9ab	1,288.1a	---	1,171.6a	---
Florida	2,424.4a	---	1,996.5 bc	1,805.7a	1,444.4 cd	---	---	---	---	---
Honduras	2,509.4a	2,173.5ab	1,908.9 cd	1,713.3a	1,489.4 c	1,390.0 b	---	---	863.0 c	992.0 b
Israel	---	---	2,208.2a	1,797.3a	1,647.5a	1,460.4a	---	1,241.6	---	1,067.9 b
Mozambique	2,028.5 b	1,691.0 d	1,592.0 f	1,371.3 c	1,170.5 e	1,076.8 d	957.6 c	---	---	---
Paraguay	---	---	1,681.0 def	1,488.5 bc	1,506.0 bc	1,234.8 c	1,104.0 bc	---	1,005.0 bc	883.0 c
South Africa	---	1,735.0 cd	1,615.2 f	1,383.7 c	1,245.8 e	1,085.3 d	954.6 c	---	972.0 bc	---
Surinam	2,219.3 b	2,208.4a	1,857.8 cd	1,552.3 bc	1,447.9 cd	1,254.9 c	1,122.6 b	1,204.0	947.2 c	1,472.0a
Ruby Red grapefruit										
Argentina	---	2,131.0	1,879.0a	1,718.5	1,424.7	1,246.0 b	1,176.0	---	1,127.5	953.0
Florida	2,671.0	---	2,112.5a	1,782.0	1,517.4	1,398.0a	---	---	---	---
Honduras	2,676.0	2,221.5	1,920.0a	1,801.0	1,539.0	1,506.0a	---	---	---	---

[1/] Means within a column followed by different letters are significantly different at 5-percent level.

TABLE 5.--Rind thickness for Marsh Seedless and Ruby Red grapefruit by country of origin and indicated count, Rotterdam, 1974[1/]

Origin	Thickness for indicated count									
	32	36	40	48	56	64	72	75	80	88
	Mm	Mm	Mm	Mm	Mm	Mm	Mm	Mm	Mm	Mm
Marsh Seedless grapefruit										
Argentina	---	8.9a	8.7ab	8.1a	7.1ab	6.9abc	6.7ab	---	6.6a	5.7ab
Brazil	---	9.5a	10.7a	9.1a	8.4a	8.3a	7.8a	---	---	---
California	---	8.2a	5.8 b	7.0ab	6.2 bc	5.9 cd	5.5abc	---	5.5ab	4.7 b
Cyprus	---	---	8.2ab	8.4a	7.1ab	7.0ab	6.2abc	---	5.1ab	---
Florida	6.2 b	---	5.6 b	5.1 b	4.5 d	---	---	---	---	---
Honduras	8.5ab	7.6a	6.2 b	5.8 b	5.7 c	5.2 d	---	---	4.1 b	4.2 b
Israel	---	---	7.8 b	7.3ab	7.0ab	6.2 bc	---	5.4	---	5.1 b
Mozambique	8.6ab	9.0a	6.6 b	5.8ab	6.4 bc	4.8 d	5.5abc	---	---	---
Paraguay	---	---	9.0ab	7.5ab	6.4 bc	4.8 d	5.3 bc	---	4.6 b	4.0 b
South Africa	---	6.4a	6.6 b	7.4ab	5.9 c	5.9 cd	5.7abc	---	4.8ab	---
Surinam	9.8a	7.6a	7.0 b	6.1ab	5.6 c	5.4 d	5.2 c	6.0	5.5ab	8.4a
Ruby Red grapefruit										
Argentina	---	5.9	4.5 b	6.2a	5.4a	4.9	3.8	---	3.9	3.9
Florida	7.1	---	5.1 b	4.3 b	4.0 b	3.7	---	---	---	---
Honduras	6.4	5.7	6.1a	5.1ab	5.7a	3.6	---	---	---	---

[1/] Means within a column followed by different letters are significantly different at 5-percent level.

Juice-to-Fruit-Weight Ratio

The means of the juice-to-fruit-weight ratios by country of origin and indicated count for Marsh Seedless and Ruby Red grapefruit are presented in table 6.

For all counts where Florida Marsh Seedless grapefruit was sampled, it had the highest juice-to-fruit-weight ratio; fruit from Honduras ranked second. Argentina, Brazil, and California generally had the lowest ratio.

Ruby Red grapefruit showed only minor differences in this ratio.

Total Soluble Solids

Percentage of total soluble solids by country of origin and by month for Marsh Seedless grapefruit is shown in table 7. Sufficient data were not available for Ruby Red grapefruit for statistical comparisons.

From January through June, Marsh Seedless grapefruit from Cyprus and Israel had the highest percentage of total soluble solids, and from July through December, this grapefruit from Surinam had the highest percentage. Marsh Seedless grapefruit from Argentina, Brazil, Mozambique, and Paraguay usually had the lowest percentage.

Total Acid

In table 8, the percentage of total acid by country of origin and by month is shown for Marsh Seedless grapefruit. For Ruby Red grapefruit, sufficient data were not available for statistical comparisons.

Marsh Seedless grapefruit from Florida had the lowest percentage of total acid for all months in which fruit was sampled, except in March and December when Surinam and Honduras had the lowest, respectively. Cyprus fruit had the highest percentage of total acid for all months in which it was sampled.

Solids-to-Acid Ratio

In table 9, the solids-to-acid ratio by country of origin and by month for Marsh Seedless grapefruit is presented. For Ruby Red grapefruit, sufficient data were not available for statistical comparisons.

For Marsh Seedless grapefruit, Florida and Surinam generally had the highest solids-to-acid ratio. This ratio was due to a low percentage of total acid and a high percentage of total soluble solids. Fruit from Argentina, Brazil, Cyprus, and Mozambique had the lowest solids-to-acid ratio.

TABLE 6.--Juice-to-fruit-weight ratio for Marsh Seedless and Ruby Red grapefruit by country of origin and indicated count, Rotterdam, 1974[1/]

Origin	Ratio for indicated count									
	32	36	40	48	56	64	72	75	80	88
				Marsh Seedless grapefruit						
Argentina	---	41.3ab	38.3 d	39.9a	41.9 bc	40.5 c	37.3a	---	37.4 b	41.4ab
Brazil	---	40.8ab	39.2 cd	39.9a	38.9 c	37.0 c	44.0a	---	---	---
California	---	39.7ab	43.1abcd	41.0a	41.3 bc	39.1 c	36.4a	---	40.1 b	37.5 b
Cyprus	---	---	44.0abcd	41.9a	42.4 bc	41.9 bc	43.8a	---	45.0a	---
Florida	46.7a	---	47.4a	48.7a	47.6a	---	---	---	---	---
Honduras	43.4ab	45.3a	46.7a	47.8a	46.4a	47.2a	---	---	40.6ab	49.0a
Israel	---	---	44.8abc	41.8a	43.1 bc	43.2 bc	---	44.7	---	43.0ab
Mozambique	43.5ab	38.1 b	37.5 d	42.9a	41.6 bc	47.0ab	43.4a	---	---	---
Paraguay	---	---	42.8abcd	47.5a	45.9ab	46.2ab	44.9a	---	47.0a	44.4ab
South Africa	---	43.2ab	46.0ab	43.2a	45.3ab	44.5ab	42.3a	---	49.4a	---
Surinam	40.0 b	41.7ab	42.5 bcd	41.7a	43.4 bc	43.0 bc	43.3a	46.5	39.6 b	36.7 b
				Ruby Red grapefruit						
Argentina	---	49.7	54.0a	53.1a	50.2a	48.5 b	49.6	---	47.4	47.2
Florida	42.4	---	48.1a	49.7a	51.3a	53.3ab	---	---	---	---
Honduras	50.8	50.0	42.8a	52.3a	43.7 b	54.4a	---	---	---	---

[1/]Means within a column followed by different letters are significantly different at 5-percent level.

TABLE 7.--Total soluble solids for Marsh Seedless grapefruit by country of origin and by month, Rotterdam, 1974[1/]

Origin	Total soluble solids for--											
	January	February	March	April	May	June	July	August	September	October	November	December
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Argentina-----	---	---	---	----	---	7.8 d	9.0 d	10.3 bc	8.3 cd	9.9a	8.2 c	---
Brazil--------	---	---	---	---	---	8.6 cd	---	---	9.1 bc	---	---	---
California----	---	---	---	---	10.2 bc	11.6a	10.9 bc	10.3 b	9.7ab	9.6a	---	10.5a
Cyprus--------	12.3a	12.4a	12.9a	11.7a	---	---	---	---	---	---	8.9 bc	10.1a
Florida-------	---	10.3 b	11.5 b	---	---	7.1 d	---	---	7.8 d	9.2a	8.1 c	8.0a
Honduras------	9.6 b	10.4 b	9.6 c	9.9 c	10.0 bc	---	11.3ab	12.3a	9.3 bc	9.2a	8.8 c	8.7a
Israel--------	11.7a	11.8 b	11.6 b	11.5a	11.1a	10.5 b	---	---	9.5abc	9.6a	9.6 b	10.0a
Mozambique----	---	---	---	---	9.2 c	7.6 d	---	8.8 bcd	---	5.9 b	---	---
Paraguay------	---	---	---	---	---	9.7 bc	9.5 d	7.9 d	---	---	---	---
South Africa--	---	---	---	---	10.7ab	9.6 c	10.0 cd	8.4 cd	9.0 c	10.7a	---	---
Surinam-------	9.8 b	---	9.8 c	10.6 b	---	---	12.4a	11.1ab	10.3a	10.6a	10.5a	10.4a

[1/]Means within a column followed by different letters are significantly different at 5-percent level.

TABLE 8.--Total acid for Marsh Seedless grapefruit by country of origin and by month, Rotterdam, 1974[1/]

Origin	Total acid for--											
	January	February	March	April	May	June	July	August	September	October	November	December
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Argentina------	---	---	---	---	---	1.9ab	1.8 b	2.1a	1.9a	1.8 b	1.5 c	---
Brazil---------	---	---	---	---	---	1.9a	---	---	1.9a	---	---	---
California-----	---	---	---	---	1.4a	2.1a	1.8 b	1.7 b	1.7a	1.5 c	---	1.8 bc
Cyprus---------	2.3a	2.1a	2.2a	1.9a	---	---	---	---	---	---	2.2a	2.2a
Florida--------	---	.9 c	1.4 cd	---	---	.8 e	---	---	1.4 b	1.2 d	1.4 c	1.6 cd
Honduras-------	1.7 b	1.8 b	1.6 c	1.6 b	1.4a	---	1.8 b	1.9ab	1.7a	1.7 bc	1.5 c	1.4 d
Israel---------	2.1a	2.0 b	2.0 b	1.7a	1.6a	1.4 d	---	---	1.9a	1.9a	1.9 b	1.9 b
Mozambique-----	---	---	---	---	1.5a	1.6 bcd	---	1.3 b	---	1.2 d	---	---
Paraguay-------	---	---	---	---	---	1.6 bc	1.6 b	1.4 b	---	---	---	---
South Africa---	---	---	---	---	1.6a	1.5 cd	1.6 b	1.5 b	1.6a	1.7 bc	---	---
Surinam--------	1.3 c	---	1.1 d	1.1 c	---	---	2.4a	2.1a	1.7a	1.6 c	1.8 b	1.7 c

1/Means within a column followed by different letters are significantly different at 5-percent level.

TABLE 9.--Solids-to-acid ratio for Marsh Seedless grapefruit by country of origin and by month, Rotterdam, 1974[1/]

Origin	Solids-to-acid ratio for--											
	January	February	March	April	May	June	July	August	September	October	November	December
Argentina------	---	---	---	---	---	4.1 d	5.1 b	4.3 b	4.3 c	5.5 b	5.5a	---
Brazil---------	---	---	---	---	---	4.5 d	---	---	4.9 bc	---	---	---
California-----	---	---	---	---	7.4a	5.7 c	6.1ab	6.8a	5.9a	6.4ab	---	5.8a
Cyprus---------	5.4 b	5.9 b	5.9 c	6.3 b	---	---	---	---	---	---	4.1 b	4.6 b
Florida--------	---	11.7a	8.4 b	---	---	9.2a	---	---	5.6ab	7.9a	6.4a	5.1ab
Honduras-------	5.8 b	5.7 b	6.0 c	6.3 b	7.4a	---	6.4a	6.4ab	5.6ab	5.5 b	5.9a	6.1a
Israel---------	5.7 b	6.0 b	5.9 c	6.6 b	7.2a	7.7a	---	---	4.9abc	4.9 b	5.2a	5.2ab
Mozambique-----	---	---	---	---	6.2 b	4.8 d	---	6.8ab	---	4.8 b	---	---
Paraguay-------	---	---	---	---	---	6.0 bc	5.8ab	5.6ab	---	---	---	---
South Africa---	---	---	---	---	6.8ab	6.6 b	6.1ab	5.8ab	5.6ab	6.2ab	---	---
Surinam--------	7.4a	---	9.4a	9.7a	---	---	5.6ab	5.2ab	6.1a	6.6ab	5.8a	6.3a

[1/]Means within a column followed by different letters are significantly different at 5-percent level.

Relationship of Various Quality Factors

Table 10 gives the correlation coefficients between the various quality factors of Marsh Seedless and Ruby Red grapefruit from all origins.

For Marsh Seedless fruit, more significant correlations were found than for Ruby Red partly because of more samples. However, where significantly positive or negative correlations were found for Marsh Seedless grapefruit, they were the same as those for Ruby Red.

Table 11 presents the correlation coefficients by origin between the juice-to-fruit-weight ratio, the percentage of total soluble solids, the percentage of total acid, and the solids-to-acid ratio for Marsh Seedless and Ruby Red grapefruit.

Many significant correlations were found between these quality factors for Marsh Seedless grapefruit from Honduras, Mozambique, South Africa, and Surinam but only a few significant correlations for fruit from Argentina, Brazil, Cyprus, Florida, and Paraguay. Where significant correlations were found between the juice-to-fruit-weight ratio and the percentage of total soluble solids and the percentage of total acid, they were negative except for Marsh Seedless fruit from Mozambique and Ruby Red fruit from Florida, where a positive correlation was seen.

Between the juice-to-fruit-weight and the solids-to-acid ratios, a significantly positive correlation was found at the 1-percent level for Marsh Seedless fruit from Mozambique and Surinam and for Ruby Red fruit from Argentina. A significantly positive correlation was seen between the percentage of total soluble solids and the percentage of total acid except for Marsh Seedless fruit from Argentina, Cyprus, and Florida and for Ruby Red fruit from Argentina and Florida. Marsh Seedless grapefruit had a significantly positive correlation between the percentage of total soluble solids and solids-to-acid ratio from all origins except California, Cyprus, and Surinam and Ruby Red fruit from Argentina and Honduras. Between the percentage of total acid and the solids-to-acid ratio, a significantly negative correlation was found for all grapefruit except for Marsh Seedless fruit from Brazil, Mozambique, and Paraguay.

DISCUSSION

The results of this study indicate that there are both physical and chemical differences in the characteristics of grapefruit from different origins. Importers, wholesalers, or retailers can satisfy consumer preferences or tastes by buying grapefruit from certain countries of origin. Exporters or trade associations can also promote their grapefruit according to the differences in physical and chemical characteristics.

Generally a heavier fruit per given size will have a thinner rind and therefore more juice, or a higher juice-to-fruit-weight ratio, or both. Marsh Seedless grapefruit from Florida had a significantly thinner rind than grapefruit from all other origins except Paraguay. Florida and Honduras grapefruit had a significantly higher juice-to-fruit-weight ratio than grapefruit from

TABLE 10.--Correlation coefficients between various quality factors for Marsh Seedless and Ruby Red grapefruit from all origins, Rotterdam, 1974 [1/]

Quality factors	Fruit size	Fruit weight	Rind thickness	Juice volume	Juice-to-fruit-weight ratio	Percentage of total soluble solids	Percentage of total acid
			Marsh Seedless grapefruit				
Rind thickness	0.575**	---	---	---	---	---	---
Fruit weight	.948**	---	0.430**	---	---	---	---
Juice volume	.855**	0.935**	.237**	---	---	---	---
Juice-to-fruit-weight ratio	.034	.123**	-.407**	0.456**	---	---	---
Percentage of total soluble solids	-.074*	-.057	-.044	-.085*	-0.094*	---	---
Percentage of total acid	-.167**	-.277**	.115**	-.352**	-.298**	0.409**	---
Solids-to-acid ratio	.132**	.246**	-.146**	.294**	.207**	.360**	-0.668**
			Ruby Red grapefruit				
Rind thickness	.580**	---	---	---	---	---	---
Fruit weight	.976**	---	.531**	---	---	---	---
Juice volume	.893**	.927**	.328*	---	---	---	---
Juice-to-fruit-weight ratio	-.149	-.120	-.499**	.254	---	---	---
Percentage of total soluble solids	-.044	-.030	-.146	-.043	-.050	---	---
Percentage of total acid	-.491**	-.512**	.086	-.574**	-.248	-.021	---
Solids-to-acid ratio	.342*	.357**	-.160	.372**	.086	.603**	-.777**

[1/] ** = significant at 1-percent level; * = significant at 5-percent level.

TABLE 11.--Correlation coefficients by origin between juice-to-fruit-weight ratio, percentage of total soluble solids, percentage of total acid, and solids-to-acid ratio for Marsh Seedless and Ruby Red grapefruit, Rotterdam, 1974[1/]

Origin	Juice-to-fruit-weight ratio			Percentage of total soluble solids		Percentage of total acid
	Percentage of total soluble solids	Percentage of total acid	Solids-to-acid ratio	Percentage of total acid	Solids-to-acid ratio	Solids-to-acid ratio
			Marsh Seedless grapefruit			
Argentina------	0.046	0.077	-0.023	0.120	0.742**	-0.554**
Brazil---------	-.402	-.335	-.202	.642*	.691*	-.110
California-----	-.306**	-.185	-.018	.486**	.078	-.791**
Cyprus---------	-.374**	-.084	-.263	.197	.727	-.527**
Florida--------	.227	-.218	.361	-.116	.825**	-.623**
Honduras-------	-.324**	-.316**	.048	.562**	.236**	-.661**
Israel---------	.033	-.025	.018	.367**	.315**	-.750**
Mozambique-----	.765**	.445*	.563**	.423*	.825**	-.154
Paraguay-------	.313	.068	.327	.549**	.802**	-.055
South Africa---	-.050	-.448**	.315*	.354**	.683**	-.427**
Surinam--------	-.277**	-.463**	.360**	.427**	-.017	-.883**
			Ruby Red grapefruit			
Argentina------	-.099	-.700**	.775**	.497	-.045	-.883**
Florida--------	.139	.465*	-.180	-.072	.759**	-.678**
Honduras-------	-.260	-.518*	.347	.580*	.306	-.587*

[1/] ** = significant at 1-percent level; * = significant at 5-percent level.

all other origins except Paraguay. Ruby Red grapefruit from Florida had a significantly thinner rind than fruit from the other countries; however, there was no significant difference in the juice-to-fruit-weight ratio between origins.

Generally grapefruit with higher solids-to-acid ratio is more palatable or sweeter than fruit with lower ratios (4). Grapefruit can have a high amount of total soluble solids, which is about 80-percent sugars, and also a high amount of total acid and therefore a low solids-to-acid ratio and a low palatability. Marsh Seedless grapefruit from Florida and Surinam had a significantly higher solids-to-acid ratio than fruit from other origins. This grapefruit from Florida also had a significantly lower percentage of total acid than that from other origins and also had a significantly higher percentage of total soluble solids than grapefruit from all other origins except Argentina, Brazil, Mozambique, Paraguay, and South Africa.

Some consumers like tart grapefruit, which generally has a lower solids-to-acid ratio and a higher percentage of total acid. Marsh Seedless grapefruit from Argentina and Brazil had a significantly lower solids-to-acid ratio than that from all other origins except Cyprus and Mozambique. This grapefruit from Cyprus had a significantly higher percentage of total acid and total soluble solids than grapefruit from all other origins. Ruby Red grapefruit from Argentina and Honduras had a significantly lower solids-to-acid ratio and also a significantly higher percentage of total acid than fruit from Florida, but there was no difference in the percentage of total soluble solids.

LITERATURE CITED

(1) Anonymous. 1971. Regulations (EEC) No. 379/71 of the Commission, February 19, 1971. Off. Jour. European Communities No. L45/1, 18 pp. Brussels, Belgium.

(2) Centraal Bureau voor de Statistiek. 1976. Basisstatistieken van de gemeenschap 1973-1974. 224 pp. The Hague, the Netherlands.

(3) Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11: 1-7.

(4) Harding, P. L., and Fisher, D. F. 1945. Seasonal changes in Florida grapefruit. U.S. Dept. Agr. Tech. Bul. 886, 100 pp.

(5) Kramer, C. Y. 1956. Extension of multiple range tests to group means with unequal numbers of replication. Biometrics 12: 307-310.

(6) Long, W. G., Harding, P. L., Soule, M. J., Jr., and Sunday, M. B. 1959. Variations in quality of Marsh grapefruit. U.S. Dept. Agr. AMS-336, 27 pp.

(7) Long, W. G., Harding, P. L., Soule, M. J., Jr., and Sunday, M. B. 1960. Variations in quality of Florida grown Duncan grapefruit. U.S. Dept. Agr. AMS-420, 16 pp.

(8) Organization for Economic Cooperation and Development. 1971. International standardization of fruit and vegetables; citrus fruit 1971. 86 pp. Paris, France.

(9) Rygg, G. L., and Getty, M. R. 1955. Seasonal changes in Arizona and California grapefruit. U.S. Dept. Agr. Tech. Bul. 1130, 44 pp.

(10) Soule, J., Grierson, W., and Blair, J. G. 1967. Quality tests for citrus fruit. Univ. Fla., Agr. Ext. Serv., Inst. Food and Agr. Sci. Cir. 315, 27 pp.

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